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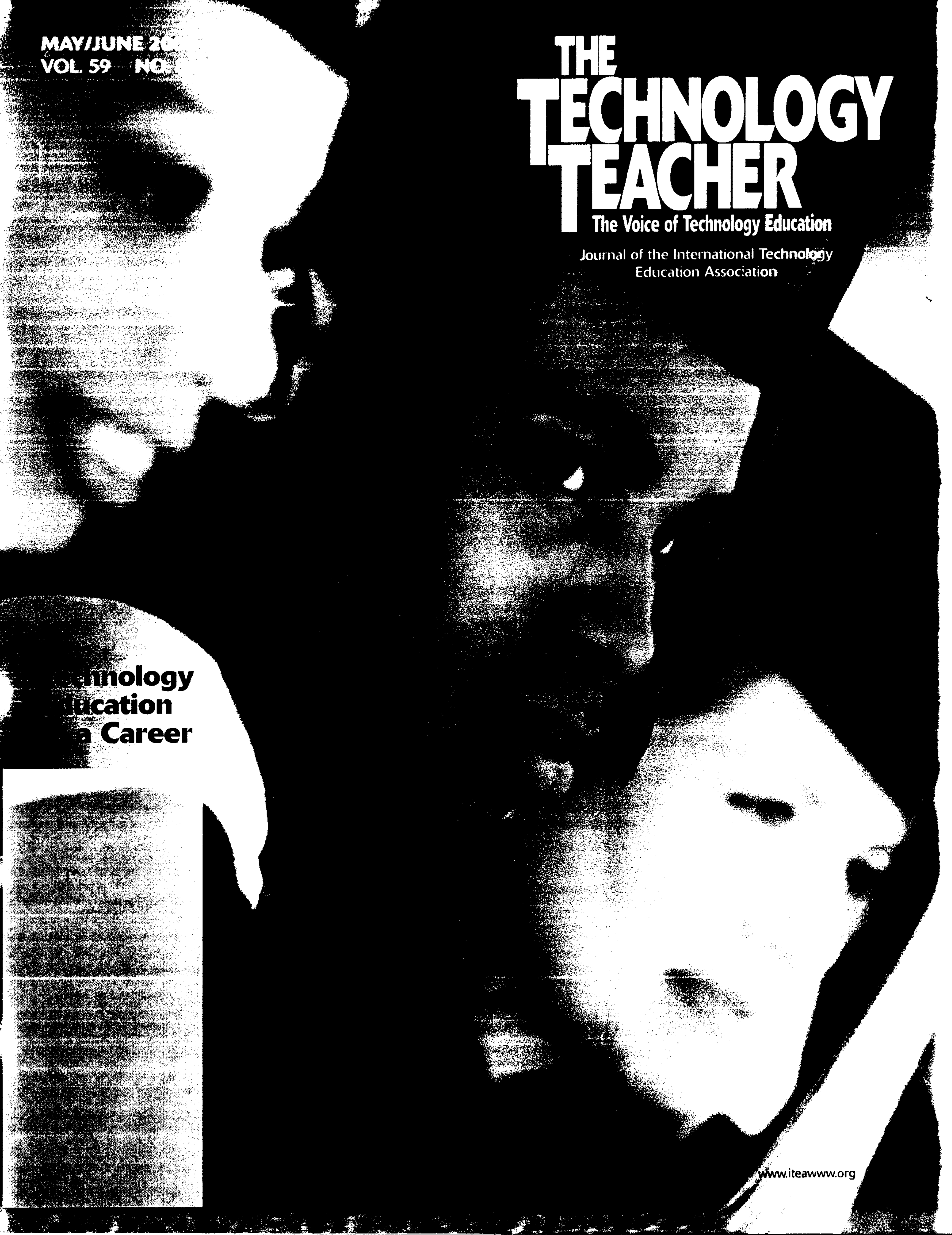

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Getting in Touch with Your Inner Spacecraft

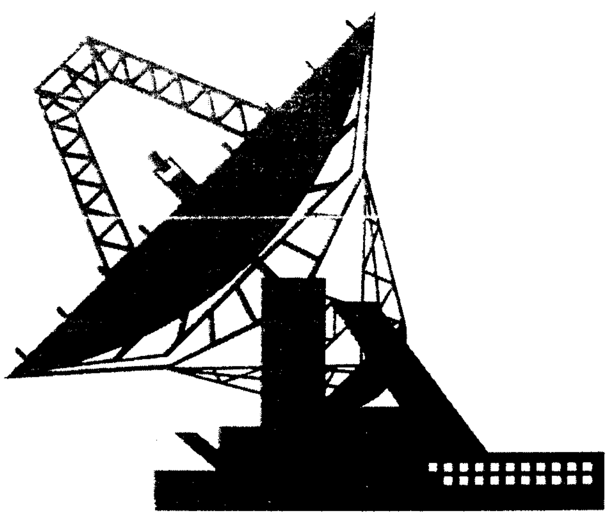
Editor's Note:

Space weather is a subject of increasing scientific inquiry. In this activity, students learn what space weather is and what is being done to study it. It is an outdoor activity, fun and adaptable for the primary through middle school grades. The article is written to be photocopied and given to the students to supplement the activity.

The Space Technology 5 (ST-5) mission described in this article is being developed at the National Aeronautics and Space Administration's (NASA's) Goddard Space Flight Center (GSFC). It will test several new technologies, including those necessary for multiple spacecraft to fly in a cluster and function as a single system to take space weather measurements. Thanks to Doug McLennan of GSFC and Yoaz Bar-Sever of the Jet Propulsion Laboratory (JPL) for their contributions to this article.

Activities and fun facts related to this and other space missions can be found on The Space Place, JPL's Web site for children, at **http://spaceplace.jpl.nasa.gov**. More information about ST-5 and NASA's other New Millennium Program missions to space validate new technologies that can be found at **http://nmp.jpl.nasa.gov**.

The article was written by Richard Shope and Diane Fisher at JPL. Richard is the Space Science Education Outreach Liaison and Diane is a science and technology writer and developer of The Space Place Web site. Artwork is by Alexander Novati at JPL. The research described in this article was carried out by NASA's Goddard Space Flight Center, Greenbelt, Maryland; and the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, under a contract with NASA.



Getting in Touch with Your Inner Spacecraft

Imagine this:

All your friends know that you are very interested in space science and technology. At your next birthday party, they team up to bring you a gift, nicely wrapped up in a box not much bigger than your birthday cake. When you open it, you find . . . hmmmm.

"What is it?" you ask.

"Well, it's a nanosat, of course!" they all chime in. "It's a miniature spacecraft that has everything it needs!"

"What's it do?" you ask.

One by one, your friends reply:

"It flies in a cluster with two other nanosats just like it."

"Together they know where they are in space at all times."

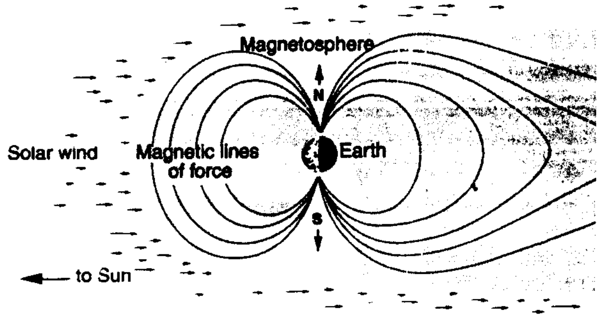
"They can fire thrusters to reposition themselves to stay in the cluster and keep pointed in the right direction—without tumbling, which is not always so easy in space."

"They communicate with engineers and scientists on Earth."

"And they do experiments to help us learn how to study space weather."

"Wow!" you reply. "It's not just a toy, it's the real McCoy!"

Three nanosatellites like this are being developed by the National Aeronautics and Space Administration (NASA) as a gift to the whole world. These spacecraft will fly as the Space Technology-5 mission (ST-5). ST-5 will help to advance the technologies needed to fly future space missions that will study space weather.

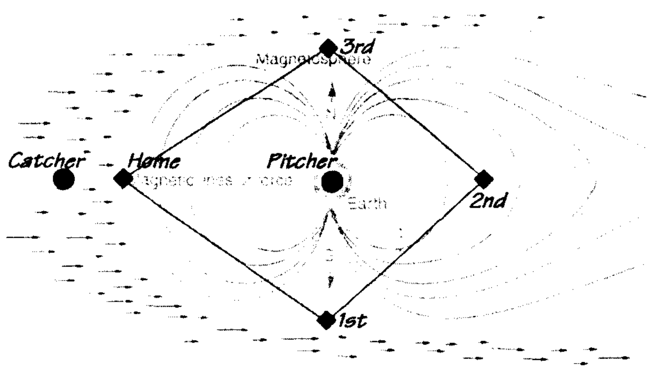


WHY DO WE EXPLORE SPACE WEATHER?

We usually think of weather as the effects of changes in Earth's atmosphere. For example, clouds bring rain or snow. Space weather is how the Sun's activity affects the Earth above our atmosphere in a region called the magnetosphere. The magnetosphere is the area around Earth that is affected by Earth's magnetic field. This is where a lot of our Earth-orbiting satellites are.

We all know that Earth has climate changes. Our star (the Sun) cycles through major climatic changes of its own about every eleven years. This year we are entering a period known as "solar maximum," as the Sun becomes hotter and more active than usual.

The Sun throws off a continuous stream of accelerated particles, called the solar wind. During its solar maximum, the Sun spews out more energetic charged particles than usual. When the solar wind reaches Earth's magnetosphere, most of the charged particles are deflected away from Earth, but some of them get trapped in the magnetosphere. These can create dramatic electromagnetic storms and auroras, those beautiful glowing red, green, and blue ribbons of light that can be seen from northern or southern latitudes. Some space weather storms have knocked out communication satellites, disrupted ship and airplane navigation systems, messed up telephone service and TV reception, and even caused massive power outages on Earth. And, as



you can imagine, orbiting spacecraft and astronauts—not protected by Earth's atmosphere—can really get blasted.

So these nanosats will test new technologies that will help us learn more about space weather.

AN ARMADA OF WEATHER STATIONS

A good way to study space weather is to fly several spacecraft in a cluster though an area of space, each spacecraft sampling and measuring the particles in its path. Taking several samples at the same time over a known area in space gives us much more information than just getting single point samples from a lone spacecraft. Similar to reporting the weather in a region that has both high mountains and low valleys, just having one weather station on top of the mountain isn't going to give you a very accurate report-even if you load it on a truck and rush down to the valley to take another measurement an hour later.

But how can several spacecraft be made to fly as if they were one? NASA's Space Technology 5 (ST-5) mission will test some new technologies that, hopefully, will do just that. ST-5 will fly three nanosatellites in a very elongated orbit around Earth. Part of the time the satellites will be inside Earth's magnetosphere and part of the time they will be outside it, unshielded from the solar wind. With no help from humans, the nanosats will be able to accurately maintain their positions relative to other spacecraft in the cluster, even though sometimes they will be as close as 100 meters (330 feet) and other times as far apart as 5000 kilometers (3000 miles).

That's not an easy task for humans, much less nanosats. See for yourself by going outside and doing the following experiment with your classmates.

CLUSTER FLYING THROUGH THE MAGNETOSPHERE

It's fun to do this experiment on a baseball diamond. Pretend that the pitcher's mound is Earth. Then home plate marks the boundary of the magnetosphere on the Sun side (that is, the day side); first and third bases mark the boundaries on the dawn and dusk sides; and the outfields are inside the magnetosphere on the night side of Earth. The pressure of the solar wind pushes on the Sun side of the magnetosphere, as the charged particles from the Sun are deflected by Earth's magnetic field. The magnetosphere trails way out into space on the night side.

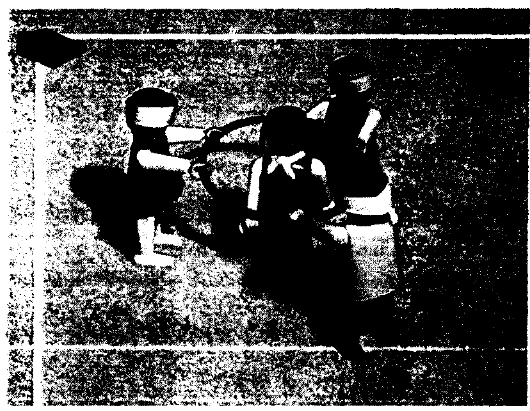
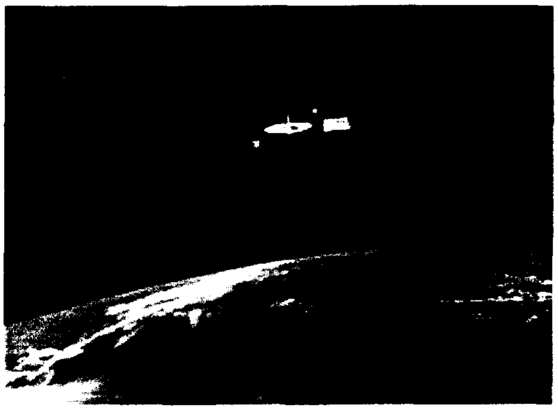


Photo by Ben Toyoshima and Liliana Novati

You will need a few plastic hoops (such as Hula Hoops®) for this experiment—maybe one for every 6 or 8 people in the class. You will also need some scarves or handkerchiefs to use as blindfolds.

Getting in Touch with Your Inner Spacecraft



Trial 1: Let the hoops represent how nanosats stay in a cluster. The nanosats use radio communication and attitude thruster adjustments instead of hoops.

Form teams of three. Position the three people evenly around the outside of a hoop, each person facing the center and holding on to the hoop with both hands.

Starting about halfway between the pitcher's mound (Earth) and home plate, begin to "orbit" Earth, everyone moving together and keeping the hoop horizontal. Speed isn't at all important. Just try to move smoothly and together, trying to sense through your hands the general direction the group is moving.

Make your orbit elliptical, with one side far from Earth and the other side fairly close to Earth. If you step between home plate and the catcher's area, you will be outside the Earth's protective magnetosphere. That's OK, but just remember you have to be very tough to withstand all that solar wind!

Did you have any trouble staying together and moving smoothly? Did your team get better after you all got a feel for moving together?

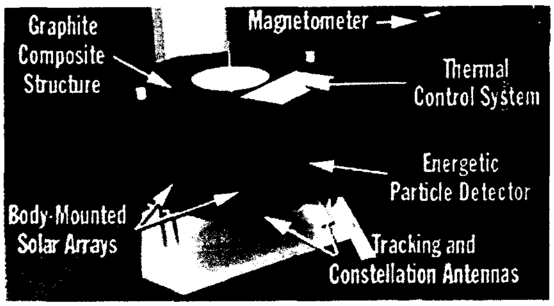
Trial 2: *The person in the middle adds to the challenge of staying organized in a cluster. The nanosats have to stay together at about the same distance, moving smoothly.*

This time, break into teams of four. Put three people around the outside of the hoop, as before, but this time put the fourth person in the middle of the hoop. The person in the middle does not touch the hoop at all.

Now, do your orbits again, but everyone on the team must work to make sure the person in the middle does not touch the hoop. Again, it's not a race! It's OK to talk to each other and agree which direction to go or how fast or slow. You might even want to elect a spacecraft commander.

Now this takes teamwork! Did you find this much harder than the first trial? How many times did the person in the middle make contact with the hoop or the hands? How did you each know what direction and how fast to move?

Trial 3: *Blindfolds add to the challenge by having voice communication represent radio communication among the nanosats.*



Stay with your team of four. The rules of this trial are the same as for Trial 2, except the three people on the outside of the hoop are blindfolded. The person in the middle is the spacecraft commander, telling everyone else what to do. You'd better take it slow so no one stumbles and so the commander remains untouched.

This one is really difficult. The blindfolded people have to rely on touch and hearing to navigate. The commander has to think fast and talk clearly to keep everyone together.

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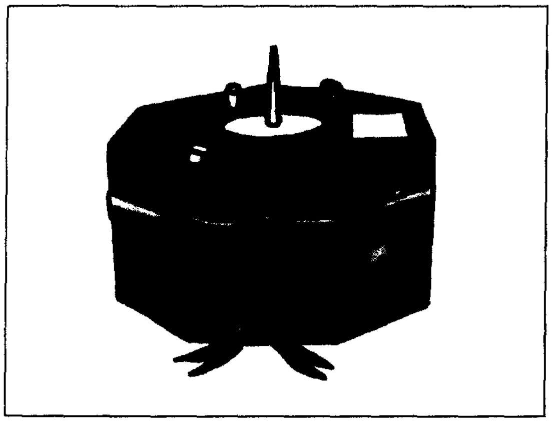

How did it feel to move around in an open space without being able to see? Did you find yourself feeling confused about which direction you were facing or where you were on the baseball diamond? As commander, did you feel that your teammates had put their trust in you and that it was your duty to keep them safe?

Trial 4: *With all the previous practice, the teams are ready to fly in clusters without touching!*

Now, forget the blindfolds and plastic hoops, and get back into teams of three.

Stand facing your teammates, far enough apart to extend your arms from your sides a bit. Now, make as if you are going to hold hands, but don't quite touch. Leave about two or three inches between your palms. Pretend that your hands are receiving signals transmitted by the other people's hands. If you concentrate hard enough, maybe you can feel them!

Now, again start to move together through your orbits through Earth's magnetosphere. Move slowly and smoothly, always trying to keep the same distance between your hands. You might find that talking only makes it harder to concentrate.

How did you do? Did this trial make you feel different inside from the other trials where you actually had something to hold onto? Did you feel differently about your teammates during this trial? If so, how?

You each have to be very tuned in to your teammates to move together as one with no help from the outside. The three separate ST-5 spacecraft have a similar challenge. And, in addition to keeping track of each other and moving together as if they were one, they have to know precisely where they are with respect to points on Earth's surface below. Then, of course, there are the tasks of scientific discovery, such as measurements of charged particles, which must be coordinated among the spacecraft.

MINIATURIZING SPACECRAFT TECHNOLOGIES

Not only are these spacecraft very clever and agile, but they are very, very small to have all these abilities. Most current spacecraft that can do most of these things are much bigger, weighing at least 100 kilograms (220 pounds). Each ST-5 nanosatellite will weigh only 21.5 kg (47 pounds). It is much less expensive to launch lighter objects into orbit. Adding even one kilogram to the weight of the payload (in this case, the satellite) greatly increases the rocket fuel required to lift the payload into orbit. And, of course, the fuel itself weighs a lot, requiring even more fuel to boost the extra fuel for the payload!

Packing all these capabilities into the small ST-5 satellite package will require very advanced microelectronics and other spacecraft component technologies. The ST-5 mission will be a testing ground that will blaze the trail for future missions of discovery using many spacecraft working together as one.